

# APPENDIX 1

## GUIDANCE FOR CONDUCTING AND REPORTING DETAILED GEOLOGIC AND HYDROLOGIC INVESTIGATIONS AT A PROPOSED SOLID-WASTE DISPOSAL AREA



**Missouri Department of Natural Resources**  
**Division of Environmental Quality**  
**Division of Geology and Land Survey**

This appendix contains the following:

- Elements and format of a workplan for conducting the Detailed Site Investigation.
- Guidance for conducting an acceptable detailed geologic and hydrologic investigation of a proposed solid-waste disposal area.
- Guidance for the acceptable presentation of site characterization data.
- Form for requesting a preliminary investigation for a proposed solid-waste disposal area.

### ELEMENTS AND FORMAT OF A DETAILED SITE INVESTIGATION WORKPLAN

The detailed site investigation workplan must contain the following elements plus any additional site-specific elements which may be requested by the Geological Survey Program (GSP).

1. Topographic map at a scale of 1:24,000 showing the pertinent property boundaries, as well as the location of the proposed solid-waste disposal area, and potential borrow areas
2. Site map at a suitable scale to display proposed locations for pits, borings, and piezometers
3. A general description of the proposed facility to include:
  - a. Maximum depth of excavation
  - b. Total acreage to be developed as a solid-waste disposal area
4. Description of proposed methods for site exploration to include:
  - a. Drilling methods
  - b. Sampling methods
  - c. Piezometer and monitoring well construction methods (must comply with 10CSR23-4):
    - (1) Approximate depth intervals to be screened
    - (2) Specific grout mixtures and emplacement methods to be used
  - d. Aquifer test methods
  - e. Alternative exploration methods (such as geophysical methods)
5. Record keeping procedures for:
  - a. Well logs, boring logs, drilling logs, pit logs
  - b. On-site precipitation data
  - c. **Periodic water-level measurement data from piezometers**
  - d. **Aquifer test data**

## DETAILED SITE INVESTIGATION

### General Procedures for Detailed Site Investigations

The potential disposal area construction permit applicant is responsible for retaining a qualified groundwater scientist to provide the GSP with a complete and accurate evaluation of the geologic and hydrologic conditions of the proposed solid-waste disposal area. All geologic and geohydrologic work must be completed under the direction of a geologist registered in the State of Missouri per RSMo 256.450 through 256.483 and the rules promulgated pursuant thereto. A consultant who subcontracts the drilling of piezometers or monitoring wells must hold a restricted or a nonrestricted monitoring well installation contractor's permit. Drilling must be done by a driller holding a nonrestricted monitoring well installation contractor's permit and appropriate permit numbers must be prominently displayed on all drill rigs used for site characterization, as required by 10 CSR 23 Chapters 1,2 and 4. **The detailed site investigation is intended to provide the GSP with sufficient geohydrologic data to determine if the site is suitable for the development of a solid waste disposal area.**

The minimum *[standards for]* **elements** of a detailed site investigation are partially dependent on site-specific geologic conditions. As a result of data gathered during the **preliminary or** detailed site investigation, the GSP may require additional investigations to adequately define the geology and hydrology of the site. **The GSP may require less detailed investigation based upon site geohydrologic conditions.**

Geophysical methods may be used to help characterize the site; however borings or pits must be located and drilled to verify the results of the geophysical survey(s). Where geologic structures or solution features *[which negatively impact groundwater monitoring or the structural integrity of a disposal area]* are present or suspected, additional borings or pits will be required to adequately define the extent and distribution of these features across the site, and to determine the relationships between these features and *[geologic]* **hydrostratigraphic** units.

Sinkholes, solution-enlarged fractures and caves may have very small, near-surface expressions that a boring program would not be expected to detect. Sites will *[routinely]* be rejected during preliminary **or** detailed site investigations where the site is characterized by *[solution features]* **karst terrane** features which may *[negatively impact groundwater monitoring or]* **affect the structural integrity or effective monitoring of [a disposal area] the site.**

### Field Direction

A qualified groundwater scientist must direct the excavation of all pits, the drilling of all borings, the performance of any geophysical surveys, and the installation, development and abandonment of all exploratory wells or piezometers. Interpretations of geological data must be conducted under the direction of a geologist registered in the State of Missouri per RSMo 256.450 through 256.483.

A qualified groundwater scientist must supervise all field testing to determine the geologic and hydrologic characteristics of the material encountered or intended for use at the proposed site. A qualified groundwater scientist must maintain accurate and complete field notes of the investigation activities.

A land surveyor registered in the *[s]*State of Missouri must determine the location and elevation of all wells and piezometers. Borings, excavation pits and all transects performed as part of a geophysical exploration will be located to the nearest one-tenth (0.1) foot by a land surveyor registered in the State of Missouri. All elevation measurements, grid patterns, and coordinates must be established and used consistently throughout the investigation and referenced to North American Datum (NAD) 1983 and National Geodetic Vertical Datum (NGVD) 1929 or North American Vertical Datum (NAVD) 1988. Monitoring well and piezometer measuring-point elevations must be accurate to the nearest one-hundredth (0.01) foot.

### Field Investigations

The minimum requirements for conducting a detailed subsurface investigation are listed below. Alternative investigation techniques and procedures may be approved at the discretion of the GSP. Additional borings or pits may be required, subject to site-specific conditions, to fully characterize the geology of the area. The number of borings, pits, and piezometers required is dependent upon the anticipated size of the proposed disposal area and the Solid Waste Rulemaking-APPENDIX 1 Rev.doc 2/27/2006

*[existence of structural or solution features which may negatively impact groundwater monitoring or the structural integrity of the disposal area]* **site geohydrology**. Borings that are not used as monitoring wells or piezometers must be permanently abandoned and reported as per 10 CSR 23-4. Exploration pits must be backfilled using native material, compacted to natural density condition, and their locations clearly marked on site maps.

## 1. Surficial Materials

A qualified groundwater scientist must determine the thickness, and geotechnical characteristics of significant *[geologic]* **hydrostratigraphic** units, **where they exist at the site**, above competent bedrock. At least one boring must be drilled per two acres of the proposed disposal area. All borings must be extended to at least 25 feet below the anticipated disposal area sub-base grade or to competent bedrock, whichever is less. All borings must be continuously sampled. Exploration pits may be substituted for borings in areas where the surficial materials can be fully penetrated by the pits. **For sites that meet the conditions pursuant to 10 CSR 80-2.015(1)(A)3 the GSP shall require only one boring per four acres of the site.**

If geologic structures or solution features *[which negatively impact groundwater monitoring or the structural integrity of a disposal area are present or]* **are** suspected, at least one boring must be completed per acre of the proposed disposal area. All of these borings will be drilled to competent bedrock. Exploration pits may be substituted **if approved by GSP**.

The borings or pits must be distributed in a grid pattern across the site or located in a manner that will optimize characterization of the site. Deviations from a regular grid pattern must be approved by the GSP. The locations and elevations of borings or pits must be *[recorded]* **surveyed** by a *[registered]* land surveyor.

## 2. Aquifers

A qualified groundwater scientist must determine the depth, thickness and lateral extent of the uppermost aquifer(s) beneath the proposed site and additional aquifers which are potentially at risk (as determined by the GSP).

Piezometers are required to adequately characterize the groundwater at the proposed site. There must be at least five piezometers, or one piezometer per four acres of *[disposal area]* **the site**, whichever is greater, installed in each aquifer to be characterized. **For sites that meet the conditions pursuant to 10 CSR 80-2.015(1)(A)3 there must be at least five piezometers, or one piezometer per eight acres of the site, whichever is greater.** Piezometer construction and development standards must be in accordance with 10 CSR 23-4.

All piezometers must be distributed in a grid pattern across the proposed site or located in a manner that will optimize characterization of the site. Deviations from a regular grid pattern must be approved by the GSP. An adequate number of piezometers must be located outside the anticipated fill area to sufficiently characterize each aquifer **investigated**. The measuring-point elevation of the piezometers must be determined by *[survey]* **a land surveyor**. Additional piezometers may be required to demonstrate the effectiveness of confining *[beds]* **units** and extent of aquifers. If geophysical methods are used, piezometers must be installed to verify the results of the geophysical survey(s).

A continuously recording precipitation gauge, capable of measuring precipitation events greater than one-tenth (0.1) inch, must be installed at the site concurrent with, or prior to, installation of piezometers. Data from the gauge will be used to interpret any fluctuations in potentiometric level(s) throughout the site characterization period and may be used for other purposes later, at the discretion of the department.

The hydraulic conductivity of the uppermost aquifer(s) beneath the proposed disposal area must be determined. The hydraulic conductivity must be determined in one out of every four *[borings (25% of the borings drilled on site)]* **piezometers installed** for each aquifer tested. The hydraulic conductivity must be determined in the field. Accepted field tests are *in situ* slug and/or pump tests, **as determined through the workplan process**, which isolate the geologic unit of interest. *[Accepted laboratory tests to determine hydraulic conductivity include a flexible wall permeameter test or other procedure approved by the department.]*

### 3. Other [Bedrock] Hydrostratigraphic Units

**At least one boring per four acres of the proposed disposal area or five borings, whichever is greater, must be drilled to characterize hydrostratigraphic units, including the uppermost confining unit, below the anticipated sub-base grade of the site. The depth of these borings will be determined based on geohydrologic conditions at the site. At least five of these borings must be continuously sampled, unless otherwise approved by the GSP. For sites that meet the conditions pursuant to 10 CSR 80-2.015(1)(A)3 there must be at least five of these borings or one boring per eight acres of the site, whichever is greater.**

A qualified groundwater scientist must determine the **occurrence**, thickness, depth and lateral extent of the uppermost confining [bedrock] unit *[as it pertains to]* **beneath** the proposed solid-waste disposal area. If the uppermost confining unit is more than 150 feet below the lowest anticipated sub-base grade, the GSP will determine the need for characterization of the unit. *[At least one boring per four acres of the proposed disposal area or five borings, whichever is greater, must be drilled to characterize soil and bedrock units below the anticipated sub-base grade of the disposal area. At least three of these borings per soil/bedrock unit must be continuously sampled, unless otherwise approved by the GSP. The depth of these borings will be determined based upon geohydrologic conditions at the site.]* **If the thickness of the confining unit is greater than 50 feet, the depth of drilling required will be determined by GSP. The hydraulic conductivity of the uppermost confining bed must be determined by *in situ* tests in at least one out of every two, but a minimum of five, borings that penetrate the confining unit.**

For investigation of horizontal expansions and investigations near previously existing disposal areas, piezometers and borings must be located within 500 feet of the limits of the existing filled area such that there is a minimum of one piezometer per 400 lineal feet extending along the periphery of the existing filled area. As determined by the GSP, if geologic structures or features *[which negatively impact groundwater monitoring or the structural integrity of a disposal area]* are present or suspected, one piezometer/boring must be installed per 200 lineal feet along the periphery of the existing filled area. Piezometers will not be installed within the boundary of the pre-existing waste.

#### Records (Field Notes)

The geologic materials in each boring, exploration pit, piezometer or well must be logged in detail during drilling or excavation by a qualified groundwater scientist. The qualified groundwater scientist must describe and record the physical and lithologic characteristics of each geologic material encountered as well as other information pertaining to drilling or excavation. Field logs and notes pertaining to the field investigation shall be retained by the applicant **or owner/operator of a permitted solid waste disposal area** until closure.

At a minimum, a qualified groundwater scientist must, in the field, note on a descriptive log the following:

1. Texture of geologic material
2. Color (qualitative descriptions - include mottling) of geologic material
3. Relative degree of saturation (description)
4. Voids
5. Geologic origin
6. Secondary permeability features
7. Zones of incomplete sample recovery
8. Depth at which water is encountered
9. Depth and rate of drilling fluid gain or loss
10. Type and size of drilling/excavation equipment
11. Drilling rate **and penetration rate** (blow counts), **as appropriate**
12. Packer tests (intervals tested and results), **as appropriate**
13. Start and stop times for drilling/excavation
14. Names of field personnel
15. Date, time, weather conditions
16. Depth to water upon completion

All borings or pits must be observed until the water level has stabilized for at least 24 hours following completion. This observation must determine if groundwater has entered the hole, the depth to water, and, if possible, the water

bearing [zones] **hydrostratigraphic units**. During observation all borings and pits must be protected from rainfall and runoff.

#### Laboratory Analysis

All samples collected for laboratory analyses must be clearly labeled (sampling location - boring/pit number, depth, date of sample) and preserved. Soil samples not destroyed by testing and rock core must be stored, protected from the weather, and available for the GSP's inspection in Missouri until closure.

#### Laboratory Testing

A laboratory must be retained to conduct geotechnical analyses for each unconsolidated material encountered to verify field observations. The following must be recorded for each sample tested.

1. Texture
2. Color (based on a Munsell color chart - include mottling)
3. Grain size distribution (reported in percent)
4. Soil classification (reported in Unified Soil Classification System)
5. Moisture content (reported in percent)
6. Liquid Limit
7. Plasticity Index
8. Standard Proctor density
9. Names of lab personnel
10. Date

#### Monitoring Wells

While monitoring wells are not normally required as part of the detailed site investigation, background water quality data will be required prior to operation of a solid-waste disposal facility. The number of monitoring wells required will be dependent upon the presence and number of aquifers monitored and the presence and number of confining beds. Well construction standards and development must be in accordance with 10 CSR 23-4.

A minimum of one monitoring well must be located hydraulically upgradient and three monitoring wells located hydraulically downgradient for each aquifer monitored. These wells must be located outside of but not greater than 500 feet from the anticipated limit of the area. *[A minimum of four wells must be screened or open to each aquifer monitored.]* The screen and/or filter-pack must not extend through confining units.

*[For sites characterized by the GSP as having geologic structures or solution features which negatively impact groundwater monitoring or the structural integrity of a disposal area, additional monitoring wells must be installed to adequately collect groundwater data.]*

#### Water Level Data Collection

Measurements of water level, to the nearest hundredth (0.01) of a foot, must be made every month for one year for all wells and piezometers. **For sites that meet the conditions pursuant to 10 CSR 80-2.015(1)(A)3 the GSP may allow termination of water-level measurements after six (6) months.** Water-level measurements in all wells and piezometers should be made within a 48-hour [time] period, if possible. Additional measurements may be necessary as determined by the GSP.

#### PRESENTATION OF DATA AND INTERPRETATIONS

The following information must be provided in the order specified below. The report must be prepared under the direction of a qualified groundwater scientist who is a geologist registered in the State of Missouri per RSMo 256.450 through 256.483 and the rules promulgated pursuant thereto. This person must sign and seal the report.

1. Table of Contents

2. Introduction (general information about the *[study area and the study]* **site vicinity and the investigation**)
  - A. Location:  
A written narrative of the geographic setting with legal description (section, township, and range)
  - B. Regional Geology:  
A written narrative describing the regional lithologic, stratigraphic, structural and hydrologic settings of the area
  - C. Historic Land Uses:  
A written narrative describing previous land use such as mining or mineral exploration

The *[above]* sections **above** must address *[the]* **geologic conditions that relate to the siting restrictions pertaining to sites adjacent to or in the vicinity of unstable areas, faults and seismic impact zones. Other** siting restrictions listed in 10 CSR 80-3.010(4)(B) *[pertaining to sites adjacent to or in the vicinity of], including proximity to* airports, floodplains~~[,]~~ and wetlands, *[faults and seismic impact zones]* **must be addressed in the permit application.**

3. Method of Study

A written narrative must be provided which describes field and laboratory procedures used to characterize geologic and hydrologic conditions of the site. Standardized laboratory and field procedures may be referenced. All other procedures must be described in detail. **Deviations from and amendments to the approved workplan during the detailed site investigation should be described.**

4. Results of Investigation

A written detailed narrative must be provided that describes the site-specific geology and hydrology based on data collected. The narrative must include explanations of any anomalous data. Interpretations of results must be presented in a clear and concise manner.

5. Conclusions

A written narrative must be provided that details how the site-specific geology and hydrology will impact the design of the disposal area and groundwater monitoring system. The narrative must assess the inadequacies of the investigation and propose future investigations if needed. The narrative must describe the proposed monitoring system design.

6. References

All published information sources used in the compilation or research of the hydrogeologic investigation must be listed.

7. Appendices

The appendices of the site characterization report must include:

- Compiled logs of all borings, excavations, wells and piezometers.
  - The raw data for any and all tests (e.g., pumping tests)
  - All additional information that may facilitate the GSP's assessment of the acceptability of the proposed site.
- A. Logs  
Lithologic logs of all borings and excavations, including well construction diagrams, must be provided. Each log must include borehole identification, borehole grid location, soil and rock description, sample depths, methods of sampling, sampling date, land surface elevation, borehole total depth, moisture content, and test results such as: blow counts, vane shear, or pocket penetrometer measurements.
  - B. Tables  
Presentations of tabular data that must be supplied include the following:

- (1) All borehole, well and piezometer construction data. Such data should include the borehole, well or piezometer identification, grid location, total depth, surface elevation and, if applicable, screened interval and hydrogeologic unit monitored.
- (2) Monthly groundwater elevation measurements for each piezometer or well. The table(s) should indicate the well or the piezometer identification, depth to water from measuring-point, groundwater elevation and date of measurement.
- (3) The results of all unconsolidated-material testing. The table(s) must include the sample location, depth, sampling date, and test results.
- (4) The results of all hydrologic testing. The table(s) must include the well or piezometer identification, method and date of test, depths of interval tested, hydrologic unit tested and results.
- (5) The daily precipitation data collected at the site.

#### C. Maps

All detailed site maps for the report must be drawn on a scale where one inch equals 400 feet or less. As appropriate, maps should be drawn on a consistent scale. All maps must include a scale, north arrow, and a clear and concise legend describing all of the symbols used on the map. More than one map will be required to include the following information:

- (1) A base map showing initial topography (on 5 foot contour intervals unless otherwise specified by the GSP), borrow area(s), and proposed disposal area boundary.
- (2) Map(s) showing land use, ownership, residences, septic systems, lateral lines, buildings, wells, cisterns, mined or quarried areas, mine shafts, spoil piles, and all other man-made features within 1/4 mile of the proposed disposal area boundary.
- (3) Map(s) showing springs, water courses, streams, lakes, caves, sinkholes, rock outcrops, and other significant geologic features within 1/4 mile of the proposed disposal area boundary.
- (4) Map(s) showing all borings, excavations, piezometers, and wells constructed for the study.
- (5) Monthly piezometric maps per aquifer to be monitored. The maps must include labels showing water elevations next to each well or piezometer and must indicate the date when the water elevation was measured.
- (6) Map(s) showing inferred results of geophysical explorations with survey tracks (if applicable).
- (7) Map(s) locating cross-sections showing borings used in cross-section representation.
- (8) Map(s) locating floodplains, wetlands and fault(s).
- (9) Map delineating seismic impact zones.
- (10) Bedrock contour map (where applicable).

#### D. Cross-sections

Geologic cross-sections must be constructed through all appropriate borings both perpendicular and parallel to the facility baseline as well as along and across all transects which include major geologic features such as faults, sinkholes, and buried valleys. At least one cross-section must be constructed parallel to groundwater flow. The subsurface conditions of the site must be illustrated in these cross-sections. Where more than one interpretation may be reasonably made, conservative assumptions must be used.

The following information must be included on the cross-sections:

- (1) A dashed line or question mark for inferred lithostratigraphic boundaries, a number or symbol to label major soil units (instead of extensive shading) and legend containing a description of the soil units.
- (2) The anticipated sub-base, and final grades for the proposed disposal area.
- (3) All boring logs, the Unified Soil Classification System soil classifications and the geologic origin for each soil unit. The results of all lab and field tests, and all well construction details including screen and seal length along with the stabilized water elevations should be shown on the logs beside the descriptions of the materials encountered.

#### E. Aerial Photographs

One or more vertical aerial photographs, representing the entire area of the proposed site plus the area within 1/4 mile of the site must be included in the report. The photos must be taken between November 1 and March 30, within two years of the submittal of the report unless significant excavation has occurred at the site. If significant excavation has occurred at the site during the previous two years, the photos must be taken between November 1 and March 30, within one year of the submittal of the report. The extent of the proposed disposal area, the anticipated limits of the proposed fill area and a north arrow must be added to the photos. Photocopies of the photographs will not be accepted.

MISSOURI DEPARTMENT OF NATURAL RESOURCES  
DIVISION OF GEOLOGY AND LAND SURVEY, GEOLOGICAL SURVEY PROGRAM  
**REQUEST FOR PRELIMINARY INVESTIGATION OF  
PROPOSED SOLID-WASTE DISPOSAL AREA**



FOR OFFICE USE ONLY

PROJECT CODE \_\_\_\_\_

DATE RECEIVED \_\_\_\_\_

**FACILITY OR PROJECT LOCATION**

FACILITY OR PROJECT NAME

¼ ¼ SECTION	¼ ¼ SECTION	¼ SECTION	SECTION	TOWNSHIP N.	RANGE E / W	QUADRANGLE NAME
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WRITTEN LOCATION IF LEGAL DESCRIPTION IS UNAVAILABLE

COUNTY

**OWNER INFORMATION**

OWNER NAME

TELEPHONE

OWNER ADDRESS

CITY

STATE

ZIP CODE

**EVALUATION REQUESTED BY**

NAME AND COMPANY OF REQUESTOR

TELEPHONE

ADDRESS

CITY

STATE

ZIP CODE

**FACILITY INFORMATION**

TYPE OF DISPOSAL AREA PROPOSED

☐ SANITARY LANDFILL ☐ DEMOLITION LANDFILL  
☐ UTILITY WASTE LANDFILL ☐ \*\*SPECIAL WASTE LANDFILL\*

\*Please specify type of special waste \_\_\_\_\_

ESTIMATED SIZE OF DISPOSAL AREA IN ACRES

ESTIMATED ELEVATION OF THE SUB-BASE GRADE IN FEET ABOVE MEAN SEA LEVEL

\*\* A special waste is defined as "solid-waste requiring handling other than normally used for municipal waste".

**MAP MUST BE SUBMITTED WITH REQUEST!**

A topographic map must be provided with this request that contains the following information: all known wells, springs, sinkholes, caves, mines, roads, and dwellings within ¼ mile of the facility. Show the estimated boundaries of the disposal facility and any existing borings, test pits, or excavations which expose soil or bedrock. Include a scale and north arrow on the map.

COMMENTS



<b>REQUESTOR'S SIGNATURE</b>	DATE
<b>OWNER'S SIGNATURE</b> (INDICATES PERMISSION TO ACCESS PROPERTY)	DATE

MAIL COMPLETED COPY TO: **DEPARTMENT OF NATURAL RESOURCES, ENVIRONMENTAL GEOLOGY SECTION, P.O. BOX 250, ROLLA, MO 65402-0250,**  
Phone: (573) 368-2161 Fax: (573) 368-2111 E-MAIL ADDRESS: [gspgeol@dnr.mo.gov](mailto:gspgeol@dnr.mo.gov)

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